Insect collections, surveys and conservation in British Columbia in the 20th century

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INTRODUCTION

In this brief summary of insect collections, surveys and conservation efforts in British Columbia during the 20th century, we emphasize the years since 1950, occasionally referring to activities in the first half of the century for historical perspective. Because of restricted space, our intent here is to stress accomplishments rather than the historical aspects of entomologists and their work.

Researchers and managers in many fields of biology have recognized that invaluable information on biological diversity is contained with specimens in natural history collections. Such collections are also crucial in education, essential references for identification of specimens, and critical for studies in environmental biology, ecology, evolution and other fields. Consequently, there is an effort in many parts of the world to emphasize the continued and future importance of collections and to make specimen-based information available on the Internet to researchers and others (Bisby 2000; Edwards *et al.* 2000). Collections of British Columbia insects are an important source of information relevant to a number of provincial initiatives in the assessment and conservation of our biodiversity. Miller (1985, 1993) and the Biological Survey of Canada (1991) emphasize the importance of biological collections in these and other roles. The Biological Survey of Canada (Terrestrial Arthropods) promotes, develops and coordinates national initiatives in systematic and faunistic entomology. It has published several briefs outlining guidelines for successful arthropod surveys (Biological Survey of Canada 1994, 1996).

Over the years, many biological surveys have been undertaken in the province. However, there has been little attempt to document those inventories that involve insects and ascertain where the results from these might be located. Indeed, it is often unclear if voucher or residue material from these studies are available for further study or verification of records. Furthermore, we must maintain provincial initiatives in collection growth at a time when funding is being curtailed. Ironically, with the decline of funding for taxonomic research, insects collected in association with various fish/forestry interaction programs may be our best, and perhaps only, source of new records of British

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Columbia insects in the future. All faunal surveys conducted in the province should be required to submit voucher specimens to a museum collection (Miller and Nagorsen 1992) before the project is considered complete. In this way, identifications can be confirmed and valuable records made part of the developing biodiversity database. Guidelines for the preparation and deposition of such collections are part of the provincial government's Resources Inventory Committee standards (Resources Inventory Committee 1999).

This paper summarizes the current situation with respect to collections of BC insects. It also outlines some of the major surveys that have been undertaken, and notes a few of the major results. The last section details some of the ongoing biodiversity conservation initiatives that need entomological input.

COLLECTIONS

Many collections around the world contain insects collected in BC, but only a few have large holdings of specimens from the province. Scudder (1996) gives a more comprehensive list of collections housing provincial material. In general, the larger collections containing BC specimens, both inside and outside the province, are dominated by Coleoptera and Lepidoptera material, although some other orders, such as Hemiptera and Odonata, are well represented in the province's collections. Of the larger orders, Diptera and Hymenoptera show the most serious gaps in taxonomic coverage, and the apterygote taxa are poorly covered.

Provincial collections contain limited type material, especially holotypes. Most type specimens of BC taxa are housed in larger collections, especially the Canadian National Collection of Insects, Arachnids and Nematodes in Ottawa.

COLLECTIONS IN BRITISH COLUMBIA

Royal British Columbia Museum (RBCM)

The Royal British Columbia Museum's entomology collections in Victoria began accumulating with the Provincial Museum's establishment in 1886. E.H. Blackmore, a well-known lepidopterist, volunteered as curator from 1913 to 1928. Through the first half of the 1900s, holdings grew through gifts of specimens and the energetic collecting of staff members E.M. Anderson (1903-1916) and G.A. Hardy (1924-1928/ 1941-1953). Although Hardy was primarily a botanist, his insect collections on southern Vancouver Island, especially of Lepidoptera and Coleoptera, formed the backbone of the collection. The collections were never fully organized and properly stored, however, and between Hardy's retirement in 1953 and the arrival of the collection's first full-time curator, R.H. Carcasson, a lepidopterist (1973-1978), they suffered considerable neglect and damage. Carcasson was assisted by B.D. Ainscough (1972-1983) and A. Mackie (1974-1975). R.A. Cannings, the present curator, succeeded Carcasson in 1980. C.S. Guppy (1987-1993) and D.C.A. Blades (1997-present) have served as collections managers.

The RBCM has approximately 250,000 specimens; about 55,000 of these are Lepidoptera, 60,000 Coleoptera and 35,000 Diptera. Cannings' specialty, the Odonata, number 35,000. Important collections included are those of A.W. Hanham (Lepidoptera and Coleoptera), G.O. Day (Lepidoptera), T.A. Molliet (Lepidoptera), G.A. Hardy (Geometridae, Noctuidae and Cerambycidae), G. Straley (Lepidoptera), F.C. Whitehouse (Odonata) (in part), J. Grant and R. Guppy. The RBCM has a small collection of fossil insects, mainly from the Eocene shales of the Interior.

Spencer Entomological Museum (SEM)

This teaching and research museum is located in the Department of Zoology at the University of British Columbia (UBC) in Vancouver. It was founded in 1953 on the

retirement of G.J. Spencer, and is named after this outstanding teacher, prodigious collector and investigator of insect biology. Currently the museum contains 600,000 specimens (500,000 pinned, 75,000 alcohol preserved, 25,000 slide mounted) in 110 12-drawer metal cabinets.

As well as containing specimens from student collections, and voucher material associated with UBC student theses, the SEM houses some of the most important private collections made in the province over the years. These include the Buckell, Cannings (pre-1980) and Whitehouse (in part) collections of Odonata; the Buckell and Spencer collections of Orthopteroid insects; the Downes and Scudder collections of BC Hemiptera (the Alice McDouglass collection of aphids is on permanent loan to the CNC, see below); the Spencer collection of Phthiraptera and Siphonaptera slides; the Blackmore, Kimmich and Llewellyn Jones collections of Lepidoptera; the R. Guppy (in part) and Stace-Smith collections of Coleoptera (including many of the Hatch types described from the latter collection); and the Foxlee collection of Diptera and Hymenoptera. The museum also holds, on permanent loan, the small insect collection formerly maintained by the Vancouver City Museum.

G.G.E. Scudder has been the academic curator since 1965. Curators in the museum have included R.A. Cannings, S.G. Cannings, K.M. Stuart and J. van Reenen; K. Needham is the current curator. R. Kenner has been a volunteer since 1995. Because of budget retrenchments, the museum has been closed to the public since 1993.

Pacific Forestry Centre

The collection of the Canadian Forest Service, Pacific and Yukon Region, is housed at the Pacific Forestry Centre in Victoria. This collection was built mostly through the efforts of the Forest Insect and Disease Survey (FIDS) during the more than 50 years of its existence. Some of the specimens came from the federal laboratory in Vernon, which was amalgamated with the Victoria laboratory in 1969. Recently, the surveys of forest canopy biodiversity made by the University of Victoria have provided many new accessions. The Pacific Forestry Centre collection consists primarily of forest species. It is particularly well represented in Lepidoptera, bark and wood-boring Coleoptera, sawflies and hymenopteran parasitoids and predators of these groups. The collection holds approximately 100,000 specimens of 7,000 species.

D. Evans curated the collection from 1949 to 1985, assisted for much of this time by D. Ruppel. More recently, the collection has been maintained by B. Duncan, L. Humble and J. Seed. Entomologists associated with the Vernon collection before its assimilation included D. Ross and J. Grant.

British Columbia Department of Agriculture

The BC Department of Agriculture in Kelowna contains a small collection of insects relevant to agriculture in BC.

Agriculture and Agri-Food Canada

The AAFC centre at Agassiz also houses a small collection of insects relevant to BC agriculture. Some of these collections were formerly at AAFC stations in Vancouver and elsewhere in BC.

Other University Collections

Small insect collections are also contained in the Department of Biology at the University of Victoria, the Department of Biological Sciences at Simon Fraser University in Burnaby, and in the Department of Natural Resources at the University of Northern British Columbia in Prince George. These collections have specimens obtained during

teaching assignments and voucher material associated with research theses in these universities.

Private Collections

Several people in the province maintain collections that contain important material for documenting insect distribution and biology in the province. The most striking of these are the large Lepidoptera collections of C. Guppy, N. Kondla, J. Shepard and J. Troubridge. These collections made important contributions to the data analyzed and mapped in the recently published 'Butterflies of British Columbia' (Guppy and Shepard 2001). The extent and significance of private collections in the province is unknown, and an initiative to document these resources would be useful.

COLLECTIONS OUTSIDE BRITISH COLUMBIA

Many other collections in Canada, the USA and elsewhere contain specimens of BC insects (Scudder 1996). Undoubtedly the most important is the Canadian National Collection of Insects, Arachnids and Nematodes at Agriculture and Agri-Food Canada in Ottawa. This contains not only the abundant material collected in BC by government scientists and technicians over the years, but it also houses the Ricker collection of Plecoptera and the Glendenning and McGillivray collection of aphids, and much of the Forbes and Chan collection of these insects.

BC specimens are also held by the Lyman Entomological Museum at Macdonald College of McGill University in Ste.-Anne-de-Bellevue, Québec, and in the Royal Ontario Museum in Toronto. The Hopping collection of BC Coleoptera and the H.B. Leech collection of water beetles are in the California Academy of Sciences in San Francisco, together with the large collection of beetles collected by D. Kavanaugh in the Queen Charlotte Islands and elsewhere in the province. The entomological collection at Oregon State University in Corvallis houses the Hatch collection of beetles, rich in BC specimens. The American Museum of Natural History in New York and the National Museum of Natural History in Washington, DC also contain much BC material. J. Bergdahl (Spokane, WA) has a large collection of ground beetles that includes much material from BC, especially the Kootenays, Vancouver Island and the Gulf Islands. L. Crabo (Bellingham, WA) owns a significant collection of noctuid moths from the province.

COLLECTION DATABASES

Rapid access to the information contained in collections has become a major concern and a large portion of the meagre resources available to collections has been directed to the production of electronic databases. Much of the collection in the RBCM is databased and some of the insect orders in the SEM have also been computerized. The major private butterfly collections were databased during the production of 'Butterflies of British Columbia' (Guppy and Shepard 2001).

SURVEYS

Over the years surveys and inventories have increased our understanding of BC insects and their distribution. The important and wide-reaching FIDS initiative has already been mentioned. Many of the private collections made in the past, and many of those being made today, were made by collectors interested in surveying the distribution of species in their favourite groups. Recently, entomologists and naturalists have joined in informal insect forays (Cannings 1996), usually to some unstudied area, in an attempt to further knowledge of insect status and distribution. However, in the last 40 years or so, several

projects with a more or less formal survey component have been undertaken in the province. The distinction between surveys and general collecting is often not definite, and we have tried to include only the former. Most of these surveys are summarized below, emphasizing the publications produced. The surveys are arranged according to the general type of environment sampled (aquatic habitats, forests, grasslands, and so on).

In order that available resources are focused on important habitats and taxa, Scudder (1996) recommended priorities for terrestrial and freshwater invertebrate surveys. These included suggestions for surveys of Lepidoptera in the Nanaimo Lowlands and Okanagan Basin, invertebrates of coastal old-growth forests, and invertebrates in caves and springs.

AQUATIC SURVEYS

Lakes

Carl (1953), Clemens *et al.* (1938, 1939), Rawson (1934), Robertson (1954), and Withler (1956) surveyed insects and other benthic organism in a number of the larger lakes in the province. Saether (1970) studied the bottom fauna of lakes in the Okanagan Valley, paying special attention to the Chironomidae.

Scudder began surveys and detailed studies on saline lakes and other waterbodies, including peatlands, in the Cariboo, Chilcotin and Kamloops regions in 1959. These studies continued for 25 years. The physical and chemical limnology of most of the larger lakes were described by Topping and Scudder (1977), and many of the smaller ponds were characterized by Scudder (1988). Scudder (1969, 1988) listed some of the insects that showed a differential distribution in the lakes, and the community structure in the Coleoptera and Hemiptera was discussed by Lancaster and Scudder (1987). The distribution of Odonata in these same lakes was examined by Cannings *et al.* (1980) and Cannings and Cannings (1987), and the Chironomidae by Cannings and Scudder (1978).

Surveys have been an important stimulus to the development of entomological collections in British Columbia – Rob Cannings collecting chironomid larvae during a survey of saline lakes near Williams Lake, August 1970. Photo by Syd Cannings.

Some insects in meromictic lakes were listed by Northcote and Halsey (1969), and the benthic insect fauna of several lakes in the UBC Research Forest near Maple Ridge was reported in Hindar *et al.* (1988) and Rempel and Northcote (1989). Northcote *et al.* (1978), Northcote and Hall (1983), Hume and Northcote (1985), Chapman *et al.* (1985) and Walters *et al.* (1987) also gave records of the occurrence of *Chaoborus* species in some coastal and interior lakes.

Streams and Rivers

Collections of stream and river insects in BC have been made by fisheries inventory personnel of the now-titled provincial Ministry of Sustainable Resource Management, and members of the Federal Department of Fisheries and Oceans. Some of the streams studied, for which samples are available, are Loon Creek near Clinton, Centennial/ Slim/Rosanne creeks east of Prince George, Adam and Keogh rivers on northern Vancouver Island, Big Silver Creek on Harrison Lake, Mesilinka River on Williston Reservoir, Torpy and Upper Nechako rivers east and west of Prince George, respectively, and Takla Lake creeks north of Fort St. James (P. Slaney, *in litt.*)

Insects were also collected in two major fish/forestry interaction programs in coastal BC: the Carnation Creek Experimental Watershed Study on the west coast of Vancouver Island, which began in 1970 (Hartman and Scrivener 1990), and the Fish/Forestry Interaction Program (FFIP) in the Queen Charlotte Islands, initiated in 1981. Over 30 watersheds were studied in this program (Hogan *et al.* 1998). In addition, collections have been made during environmental surveys on contract to government or private industry. For instance, Perrin and Associates (Vancouver) worked for many years conducting invertebrate surveys in the Nechako River for Alcan. Unfortunately, most records for many of these studies exist only in government reports or in non-refereed documents that are difficult to locate. The species names mentioned in such "grey literature" may be unreliable, since voucher specimens are seldom deposited in provincial or university collections where they are easily accessible to taxonomic experts and where identifications can be confirmed.

Idyll (1943) studied portions of the Cowichan River and considered it a "Trichoptera" stream because of the density of these insects in the bottom fauna. Filmer (1964) surveyed the mayfly fauna in the Alouette River, and Wigle and Thommasen (1990) studied this order in the Bella Coola and Owikeno watersheds. Ricker surveyed many streams and rivers around Cultus Lake (see aquatic insects paper), and benthic insects in the lower Fraser Valley were listed by Northcote *et al.* (1976). S. Salter (pers. comm.) has followed Scudder's (1996) suggestion that collections in springs should be a priority by undertaking a preliminary inventory of invertebrates in selected warm springs and associated streams in the province.

Reece and Richardson (2000) surveyed benthic macroinvertebrate assemblages of coastal streams in the UBC Research Forest near Maple Ridge, continental streams in the Merritt area, and large rivers, namely the Fraser River near Agassiz and the Thompson River near Spences Bridge. Compared to small streams, large rivers had low invertebrate abundance, species richness and diversity. Coastal streams were richer in species, but Interior ones contained more individual insects.

Odonata Surveys

Despite the extensive collecting of Buckell (1938) and Whitehouse (1941) and the collecting and small-scale inventories of the Cannings brothers (e.g., Cannings and Cannings 1987, 1997), formal, large-scale inventories of dragonflies really were not organized until the 1990s. From 1996 to 2001, dragonfly surveys planned by the BC Conservation Data Centre and the Royal BC Museum (partly funded by Forest Renewal

BC, Parks Canada, and the Habitat Conservation Trust Fund) were undertaken to build collections, to improve understanding of species status, distribution and habitat requirements, and to better characterize the conservation status of species previously considered rare. The surveys covered southern Vancouver Island and the lower Fraser Valley; the Okanagan Valley (Cannings *et al.* 1998); the Peace River-Fort Nelson lowlands; the Columbia-Kootenay region, including the mountain National Parks (Cannings *et al.* 1999); the Cariboo-Chilcotin and Prince George-Robson Valley regions; and the Mackenzie and Omineca-Fort St. James regions. These surveys, which will continue until the whole province is covered, have added greatly to our knowledge of the distribution and ecology of this presumably well-known group of insects.

Burns Bog and other peatlands

The future of Burns Bog, the huge raised peatland near the mouth of the Fraser River, became a controversial issue in the late 1990s. In 1999 a preliminary survey of the insects of the bog was undertaken as part of the Burns Bog Ecosystem Review, an assessment of the habitat's value as a potential protected area. The results (Kenner and Needham 1999) showed that some insects in the centre of the bog were obligate peatland inhabitants, liable to be negatively affected if large areas of the bog were not conserved. Others found in the surrounding forested habitats were more widely distributed species, including a high proportion of introduced ones.

Insect surveys in other peatlands have mainly been associated with the dragonfly projects mentioned above. Seven of the 23 dragonfly species of management concern in the province inhabit bogs and fens, and surveys have focused on these habitats in the regions under study (Cannings 1994, Cannings *et al.* 1999). Much of the collecting done in the Brooks Peninsula project occurred in coastal bogs (Cannings and Cannings 1997).

FOREST SURVEYS

The most significant, long-term survey of the forests of BC is the Forest Insect and Disease Survey of the Canadian Forest Service. In BC, the FIDS collected specimens and ecological data on forest insects from 1946 to 1995.

Aided by the impressive systematic monograph on the ground beetles of Canada and Alaska by Lindroth (1961-1969), workers have undertaken several studies on carabid diversity in various forested ecosystems in the province. The variability of this diversity with succession and various logging and silvicultural practices has been stressed, largely because much of the financing for these studies has come from Forest Renewal British Columbia, a fund established in the 1990s to sustain the forest industry. Craig (1995) investigated carabid community structure in a chronosequence in the dry east coast Vancouver Island subzone of the Coastal Western Hemlock Zone. The litter spiders from this same pitfall trap study were studied by Brumwell (1996). Peak diversity in these taxa occurred in regenerating (3-8 year old) forest (Brumwell *et al.* 1998). The BC Conservation Data Centre sponsored a survey by J. Bergdahl of the rare carabid beetles in old-growth forests on Vancouver Island; results are not yet fully compiled.

McDowell (1998) examined ground beetle diversity in the Engelmann Spruce-Subalpine Fir (ESSF) and Interior Cedar-Hemlock (ICH) zones near East Barriere Lake. The ESSF forest sites had more individuals, but fewer species, than the ICH sites. Logging had a positive impact on generic and species diversity, but a negative impact on total number of individuals. Carabids in the ESSF zone were also studied by both Lemieux (1998) and Lavallee (1999), who studied the response of the carabid community to prescribed logging practices, in the Copper River Valley near Smithers, and at Sicamous Creek, respectively. Both studies showed a peak diversity following regrowth after logging. The Sicamous Creek insect surveys, largely undertaken by D. Huggerd, were part

of a larger, interdisciplinary investigation of the effects of logging on the subalpine ecosystem.

J. Jarrett (pers. comm.) investigated the much more diverse carabid community in the Interior Douglas-fir (IDF) zone at Opax Mountain, studying both the wet (IDFdk) and dryer (IDFxh) subzones. He has shown that there is much more diversity in the latter subzone, much of it shared with the adjacent grassland habitats. S. Carlson (pers. comm.) has documented the aerial dispersing Coleoptera fauna in the IDF zone at its northern limits near Fort St. James. In a comparison of the beetle fauna attracted to non-pheromone and Douglas-fir beetle pheromone baited traps, she found that a vast array of non-target beetles are attracted to the latter. In the course of this research, many species of Coleoptera new to BC were discovered.

Inventories of Collembola in forest soils have greatly increased our knowledge of the diversity and status of this important group. Vlug and Borden (1973) reported that the Collembola fauna was reduced by logging and slash burning near Maple Ridge. Marshall *et al.* (1990) surveyed springtails in forest nurseries and found 22 species, 10 of which were new to the province; observations on pest species were reported. Battigelli *et al.* (1994) examined the soil fauna in adjacent stands of old-growth Western Redcedar-Western Hemlock and Amabilis Fir-Western Hemlock forests on northern Vancouver Island and found the relative abundance of Collembola was equal in both types. In the Interior, Nadel (1999) studied the fauna of soils and litter in subalpine ecosystems as part of the interdisciplinary Sicamous Creek project.

Marshall (1993) compared the soil fauna of Coastal Douglas-fir, Interior Douglas-fir, Subalpine Fir-Engelmann Spruce and Coastal Western Hemlock forests and showed that the highest densities of Collembola occurred in hemlock forests. Addison *et al.* (1998) studied the diversity and abundance of microarthropods in successional Douglas-fir forests on Vancouver Island. The same species tended to occur in all seres studied; differences were mostly in relative and absolute abundance. Setälä and Marshall (1994), Setälä *et al.* (1995) and Marshall *et al.* (1998) studied the succession of springtails in tree stumps at the same study sites. Seventy-two species were identified; some of these were not found in the regeneration sere but most were either positively correlated with stand age or were ubiquitous. Berch *et al.* (2001) examined the diversity and abundance of springtails in the wettest subzone of the Coastal Western Hemlock Zone near Franklin River on Vancouver Island. In a comparison of habitats based on tree species, Sitka Spruce cover had the highest average number of species (21) and the highest densities (32,000/m^2).

On the Gulf Islands, Scudder surveyed insects in forested areas on the north end of Galiano Island; sweeping, beating, and window-intercept and pitfall traps were used.

As an adjunct to the ambitious survey of the insect fauna of the Yukon, mostly in the 1980s (Danks and Downes 1997), field parties on their way to the Yukon collected extensively in northern BC. Much of this collecting was in forested areas, but northern grassland and aquatic sites were also sampled.

In the 1990s, working in the canopies of Sitka Spruce forests in the Carmanah Valley on Vancouver Island, Winchester and his colleagues found more than 300 new arthropod species, many of which are restricted to habitats found only in these ancient forest treetops (Behan-Pelletier and Winchester 1998, S.A. Marshall and Winchester 1999, Winchester and Ring 1999). This work has been expanded to other biogeoclimatic zones such as the subalpine forests at Mount Cain on Vancouver Island (Winchester and Fagan 2000). Studies continue on species life cycles and factors that influence the distribution, abundance, organization and ecological importance of these aerial communities (Winchester and Ring 1999). This pioneering canopy and conservation work demonstrates that loss of unique canopy microhabitats may cause local species extinctions.

GRASSLAND AND SHRUB-STEPPE SURVEYS

Over the years, considerable collecting has been done in the interior grasslands by Buckell, the Cannings brothers, Guppy, Spencer and Scudder. Much of this work occurred in the Cariboo, Chilcotin, Kamloops, Merritt and Hat Creek regions, and results have been published in various faunistic (e.g. Scudder 1993) and systematic papers. More recently, there has been considerable insect sampling in the South Okanagan, much of this associated with the conservation of the potentially rare and endangered species and habitats there.

Cannings (1989) made a nine-year study of the robber flies of *Festuca* grasslands near Penticton. As part of the South Okanagan Conservation Areas Program, and sponsored by the Royal BC Museum, Blades and Maier (1996) published the results of a survey of grassland and montane arthropods around Mount Kobau carried out in the summer of 1991. A sampling transect from low to high elevation produced 1101 species; 12 of these were new to Canada, 12 were new to BC and two were undescribed. Subsequently, a collaborative study of the impact of livestock grazing on the Antelope-brush (*Purshia tridentata* (Pursh) DC) community was initiated; in 1994-95, Scudder studied the ground-dwelling arthropods at nine sites between Osoyoos and Vaseux Creek. The sites had different livestock grazing histories, and analyses to date show that some of the species at risk are affected by grazing, while others are not (Scudder 2000). Also, while Heteroptera diversity varies with grazing impact, ant (Heron 2001) and orthopteroid insect (S. Liu, pers. comm.) diversity does not.

In 1996, pitfall trap sampling of ground-dwelling arthropods was extended to the Chopaka and White Lake areas to examine diversity in habitats potentially suitable for the endangered Sage Thrasher. Insects were also surveyed in areas inhabited by Burrowing Owls, and their crop pellets were analyzed; they contained a high proportion of beetle remnants, especially parts of carabid, silphid and tenebrionid beetles.

In 1997-1998 pitfall trapping was continued in and around the South Okanagan to document the species of management concern that were actually confined to the South Okanagan Valley. Most were found not to occur outside the valley.

The shrub-steppe at the Desert Centre in Osoyoos has been sampled to determine changes in the ground-dwelling arthropod fauna associated with both the removal of livestock grazing and attempts at habitat restoration. Samples were taken during two years of grazing as well as after livestock were removed in 1998.

Following a number of years of pitfall trapping of arthropods associated with the Antelope-brush community on the Haynes Lease Ecological Reserve near Osoyoos, first by S.G. Cannings and then Scudder, Scudder has studied the recovery of the arthropod fauna in this community following its virtual destruction by fire on 9 July 1993. Scudder (2001) reported the fallout of airborne insects onto the reserve in the first three weeks after the fire; the highest rate was 1.768 billion/km^2/24 hrs, recorded on 22-23 July.

OTHER SURVEYS

Brooks Peninsula and other Coastal Surveys

Cannings and Cannings (1997) reported on the terrestrial arthropods collected during the RBCM's 1981 interdisciplinary expedition to study the presumed ice age refugium of the Brooks Peninsula, on the northwest coast of Vancouver Island. Over a two-week period in August, 420 species of insects in 15 orders and 139 families were collected. In addition, 34 species of spiders and 22 of oribatid mites were identified. The project found 31 species and 4 genera new to science.

The RBCM has organized other, smaller interdisciplinary surveys to the north coast. In 1950, G.C. Carl, then the Director of the Provincial Museum, along with G.A. Hardy and

other colleagues visited the Scott Islands off northern Vancouver Island to study the biogeography of these remote sites (Carl *et al.* 1951). They collected a small number of insects and other terrestrial invertebrates. In 1987 the RBCM visited Zayas and Dundas islands near the Alaska border, and the Tatshenshini River drainage in 1992.

Since the 1980s, there has been some specialized collecting on the Queen Charlotte Islands by R.A. Cannings, G.G.E. Scudder and others. D.H. Kavanaugh (California Academy of Sciences), in particular, has studied the carabid beetle fauna of the islands, first visiting them, accompanied by D.H. Mann, in July 1981. In 1986 he joined Scudder and other biologists on a survey of the biota of mainland and island localities between Vancouver and Prince Rupert. This coastal expedition aimed to confirm that the species endemic to the Queen Charlotte Islands were actually confined to the islands; most were found to be so restricted. In a monograph on the ground beetles of the Queen Charlottes, Kavanaugh (1992) listed collection data and assessed the composition, affinities and origin of the fauna.

Lepidoptera Surveys

In 1995, the BC Conservation Data Centre organized butterfly surveys to document the status of these insects in two conservation hot spots -- southeastern Vancouver Island (Shepard 1995) and the Okanagan-Similkameen valleys (S.G. Cannings, pers. comm.). Subsequently, Shepard studied the butterflies of the Peace River Lowlands (Shepard 2000) and Kondla (1999) surveyed the butterflies of south-facing slopes along the Pend d'Oreille River.

Fischer *et al.* (2000) conducted a major survey of the macrolepidoptera of the Cariboo-Chilcotin grasslands and grassland-forest interface, and reported an impressive 538 species. This is 96 per cent of the estimated total number of species in the study area. A voucher collection of over 2500 specimens was deposited at the RBCM.

These surveys contributed to the data analyzed in the 'Butterflies of British Columbia' (Guppy and Shepard 2001), the definitive work on the butterflies of the province.

Cave Surveys

Caves often contain little-known, rare and endemic species and are often threatened by groundwater changes and other disturbances. A 1995 survey initiated by the BC Conservation Data Centre examined caves on Vancouver Island (S.G. Cannings, pers. comm.). Results are not fully compiled. The first females of *Parasimulium melanderi* Stone were discovered; these rare simuliids throw light on the origins of the black fly family (Borkent and Currie 2001).

CONSERVATION

The history of insect conservation in BC is short. The first published reference to endangered insects in the province may be Scudder's (1980) symposium presentation on the Osoyoos Arid Biotic Area, in which he listed some representative invertebrates along with vertebrates and plants confined to this endangered ecosystem and emphasizes the need for conservation of all of these populations. Later, he prepared a preliminary list of the arthropod species that might be at risk in the South Okanagan (Scudder 1992). Cannings (1990) discussed the diversity of insects on a provincial scale, outlined the problems in determining conservation risk for them, and presented a short sample list of potentially endangered or threatened species. Later, Guppy *et al.* (1994) and Guppy and Shepard (2001) listed species of butterflies and skippers of conservation concern in the province.

A major problem in developing defensible lists of invertebrates of conservation concern is the lack of comprehensive inventories. Even in supposedly well-known groups

such as butterflies or dragonflies, species known from only one or two localities may be subsequently discovered to be widespread, or at least much more common than the previous collection records had indicated. But with very limited resources, the common question is, where should we start?

To help address this question, Scudder was contracted by the provincial government to develop a list of inventory priorities, and out of this work two publications emerged. One (Scudder 1994) was an annotated list of 818 terrestrial and freshwater invertebrates that, on the basis of limited known occurrence or restriction to obviously endangered habitats or ecosystems, were potentially rare and/or endangered. This list included 168 species endemic to the province (based on collection information at that time) and an additional 203 species restricted to BC in Canada. The other publication (Scudder 1996) gave a list and discussion of inventory priorities, a discussion of sampling methods and resources needed, a list of taxonomic experts, and a series of annotated lists that divided the species noted in Scudder (1994) by ecoprovince.

THE RED AND BLUE LISTS

The Red and Blue lists of species of conservation concern were originally developed for vertebrates by the Wildlife Branch in the provincial Ministry of Environment, Lands and Parks. The British Columbia Conservation Data Centre (CDC) began in 1991 as a cooperative venture of the BC Ministry of Environment, Lands and Parks, The Nature Conservancy (US), and the Nature Trust of British Columbia; it is now a section within the provincial Ministry of Sustainable Resource Management. The CDC assumed the role of assigning provincial status ranks to not only vertebrates, but to plants, plant communities, and invertebrates as well. The CDC assigns status ranks using a methodology that was created originally by The Nature Conservancy (US) and is now used by conservation data centres and natural heritage programs throughout North America and much of Latin America. The provincial Red (endangered or threatened) and Blue (vulnerable) lists of species and ecosystems are now translated directly from the CDC's ranks; up-to-date lists can be viewed or downloaded at the CDC's website (http://srmwww.gov.bc.ca/cdc/trackinglists/red_blue.htm).

All species of dragonflies, butterflies, and tiger beetles have been assigned ranks, and Scudder's (1994) list has been used to rank a number of other species where the status can be confidently assigned. Currently, 69 species of insects are on the Red List and 74 are on the Blue List. However, the problem of lack of inventories is so acute in most groups that the majority of uncommonly collected species cannot be assigned useful ranks.

The Red and Blue lists offer no direct legal protection to any species; they simply provide an account of the conservation status of species of concern within the province. Insects and other invertebrates are not considered 'wildlife' under the provincial *Wildlife Act*, so cannot be officially designated as Endangered or Threatened under that Act. However, under two more recent pieces of legislation, the *Forest Practices Code Act* and the *Fisheries Protection Act*, there is the provision for possible protection of the habitat of certain endangered insects. Under the Forest Practices Code, listed invertebrates that are deemed to be affected by forest or range practices may be designated as "Identified Wildlife" and have management practices for them specified for certain areas. A number of insects have been proposed for this designation, and have had preliminary management accounts written for them (K. Paige, pers. comm.).

NATIONAL DESIGNATIONS

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is a national body made up of representatives of federal government agencies and all provincial and territorial governments. COSEWIC has recently expanded its mandate to

include Lepidoptera, the first insect order that it has considered. Status reports have been accepted and designations made for six BC species: *Euchloe ausonides* (Lucas) *insulanus* Guppy and Shepard (Extirpated), *Plebejus saepiolus* Boisduval *insulanus* Blackmore (Endangered), *Euphydryas editha* (Boisduval) *taylori* (W.H. Edwards) (Endangered), *Satyrium behrii* (W.H. Edwards) *columbia* (McDunnough) (Threatened), *Euphyes vestris* (Boisduval) (western population, Threatened), and *Danaus plexippus* (Linnaeus) (Special Concern). These designations come with no legal protection but, under the proposed federal *Species at Risk Act*, insect species designated by COSEWIC as threatened or endangered would be recommended to the federal cabinet for official designation under that Act. National designations are detailed at the COSEWIC website at http://www.cosewic.gc.ca/cosewic/default.cfm.

RECOVERY PLANS

Once a species is designated provincially or nationally, the next stage in its conservation is the development of a recovery strategy. To date, no recovery plans have been written for specific insect species. However, recovery plans for endangered or threatened insects from the south Okanagan-Similkameen and southeastern Vancouver Island-Gulf Islands areas are now being included in the work of two ecosystem recovery teams: the South Okanagan Ecosystem Recovery Team (now part of the South Okanagan-Similkameen Conservation Program) and the Garry Oak Ecosystem Recovery Team.

BIODIVERSITY MAPPING

One way to select areas for protection is to focus efforts on sites with concentrations of species diversity and rare species. Scudder, in his research on these hotspots of richness and rarity in the province, has assembled georeferenced databases for the known, specialist-determined specimens of Odonata, Plecoptera, Hemiptera (Prosorrhyncha = Heteroptera), Lepidoptera (butterflies), Megaloptera, Raphidioptera, and Neuroptera. Databases on other groups such as carabid beetles, water beetles and aphids are being prepared. Results obtained by mapping these data with WORLDMAP software show that the provincial insect richness and rarity hotspots are in the South Okanagan and southeastern Vancouver Island-Gulf Island areas. Concentrations of rare species and total species numbers seem to coincide, and they also match similar concentrations mapped for vascular plants and small mammals.

PROTECTED AREAS

Because there is little, if any, specific protection for insects and their habitats, the general conservation of habitat in parks and other areas plays a crucial role in insect conservation. Since 1991, the area of BC protected in 'protected areas' (that is, national or provincial parks, ecological reserves, and other protected areas that fall under the *Environment and Land Use Act*) increased from 5.74 million hectares to over 11 million hectares—over 12 per cent of the province's area (BC Ministry of Sustainable Resource Management 2001). However, the ecological representation of these protected areas remains less than ideal. Even though there was some initial effort to target ecological areas that had been poorly represented in the past, 68 per cent of ecosections still have less than 12 per cent of their area protected (BC State of Environment Reporting 2000). Furthermore, a number of ecosections where endangered species are concentrated, such as the Lower Mainland and southeastern Vancouver Island, still have less than 2 per cent of their area protected.

Data on rare insect species have contributed to the success of some conservation efforts. Most of the grassland inventories noted in the present paper were undertaken in conjunction with conservation planning and strategies for protecting threatened habitats in

the Okanagan Valley. Several of these important grassland areas (e.g., Chopaka, Mt. Kobau, White Lake and Kilpoola Lake) have been preserved, either as parkland through provincial government processes, or by the Nature Trust and other conservation organizations. The results of the interdisciplinary Brooks Peninsula project were instrumental in the decision to create a provincial park there, as were the findings of the canopy studies in the Carmanah Valley. Scudder's inventories on Bodega Ridge on Galiano Island helped preserve that site, as did his aquatic surveys at Westwick and Rock lakes, now ecological reserves in the Cariboo-Chilcotin. Inventories in Burns Bog were designed to gather data for conservation purposes and, if present negotiations go well, this critical peatland may be protected in the future.

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